

CERTIFICATION

I hereby certify that this Patent Application is being deposited with the United States Postal Service on this date of December 7, 2001 in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EF223507312US addressed to the: Commissioner of Patents and Trademarks, Box PATENT APPLICATION, P.O. Box 2327, Arlington, VA 22202.

Douglas G. Glantz

(Type or print name of person mailing documents)

(Signature of person mailing documents)

ABSORBENT STRUCTURE AND METHOD

This application is a Continuation-In-Part of prior co-pending U.S. Patent Application Serial No. 09/464,133 filed December 16, 1999, now U.S. Patent No. 6,329,565.

BACKGROUND OF THE INVENTION

1. Technical Field

This invention relates to an absorbent structure and method for liquid distribution and retention. In one aspect, this invention relates to a composite absorbent structure and method for liquid distribution and retention in a disposable absorbent product. In one aspect, this invention relates more particularly to a high integrity, thin, multi functional material for liquid intake, distribution, and retention in a disposable absorbent product.

2. Background

Disposable absorbent products are used extensively for body waste management. These disposable absorbent products employ an absorbent structure or structures to manage body waste effectively. The absorbent structure or structures within the disposable absorbent product must take up and retain the body waste within the absorbent product.

liquid saturation level in an absorbent product would result in less absorbent product being disposed to the environment.

There is a need therefore to produce an absorbent structure able to exceed the liquid transport properties of known absorbent structures. There is a need also to produce an absorbent structure capable of quickly transporting liquid from a centralized insult location to a preferred, more distant location within the absorbent product.

It is an object of the present invention to provide an absorbent structure and method for liquid distribution and retention.

It is a further object of the present invention to provide a composite absorbent structure and method for use in disposable absorbent products.

It is an object of the present invention to provide a composite absorbent structure and method for use in a thin, disposable absorbent product.

It is an object of the present invention to provide a composite absorbent structure and method for use in a thin, disposable absorbent product, e.g., such as an infant diaper.

It is an object of the present invention to provide a composite absorbent structure and method for use in a disposable absorbent product having a relatively low volume.

It is an object of the present invention to provide a composite absorbent structure and method for use in a disposable absorbent product having a relatively low volume and a relatively high capacity.

It is an object of the present invention to provide a disposable absorbent product including a liquid-permeable top sheet, a back sheet attached to the top sheet, and an absorbent structure positioned between the top sheet and the back sheet,

wherein the absorbent structure provides the composite absorbent structure of the present invention.

These and other objects of the present invention will become more apparent from a review of the figures of the drawings and the detailed description which follow.

SUMMARY OF THE INVENTION

The present invention provides a composite absorbent structure and method including providing a first wicking layer having preferred liquid transport properties in a preferred contact with a second absorbent retention layer. The composite absorbent structure of the present invention provides preferred liquid transport and liquid retention properties. The composite absorbent structure has a first wicking layer in a preferred contact with the second retention layer by a novel intimate contact means effective to achieve a Contact Intimacy Ratio providing the preferred liquid transport and liquid retention functions when the first wicking layer and the second absorbent retention layer are combined together in accordance with the present invention.

In one aspect, a bonding agent is used in the present invention in combination with the first wicking layer of wettable lamellae or foams and a second retention layer of a hydrogel-forming polymeric material, preferably superabsorbent, to form a composite absorbent structure having the preferred Contact Intimacy Ratio and providing the preferred liquid transport function and the preferred liquid retention function.

In one aspect, the bonding agent used in the present invention in combination with the first wicking layer and the second retention layer includes polyhydroxyalkanoate. In one aspect, the bonding agent includes poly(lactic)acid. In one aspect, the absorbent structure has a wet geometric mean breaking length of at least 5 meters and a dry geometric mean breaking length of at

least 50 meters, and the first wicking layer exhibits a vertical liquid flux rate at a height of about 5 centimeters of at least about 0.4 grams of liquid per minute, such that the first wicking layer exhibits a wicking time of less than about 3.5 minutes, and the first wicking layer has a basis weight greater than 100 grams per square meter and less than 300 grams per square meter.

$$\text{Geometric Mean Breaking Length} = (\text{MD} \times \text{CD})^{1/2} / \text{BW}$$

where MD is the tensile strength of the web in the machine direction and CD is the tensile strength of the web in the cross-machine direction and BW is the basis weight, with all units being chosen to result in meters of breaking length. Wet breaking length is measured after the specimen is submerged in 0.9% saline for 10 to 12 seconds.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a graphical depiction of Contact Intimacy in accordance with the present invention for a model of a wicking/retention/wicking composite in a projected relationship to the appearance of a cross section of the idealized wicking/retention/wicking composite model.

Figure 2 shows a schematic cross sectional configuration of a composite absorbent structure in accordance with the present invention.

Figure 3 shows a schematic cross sectional configuration of a composite absorbent structure in accordance with the present invention.

Figure 4 shows a schematic cross sectional configuration of a composite absorbent structure in accordance with the present invention.

Figure 5 shows a schematic cross sectional configuration of a composite absorbent structure in accordance with the present invention.

Figure 6 shows a graphical depiction of Contact Intimacy results for composite absorbent structures in accordance with the present invention.

Figure 7 shows a schematic of a wicking test apparatus used in accordance with the present invention.

DETAILED DESCRIPTION

The absorbent structure and method of the present invention provide a composite absorbent for use in disposable products. The novel composite absorbent structure and method provide a first wicking layer having preferred liquid transport properties in contact with a second retention layer having preferred liquid retention properties.

The absorbent structure and method of the present invention provide a multifunctional absorbent composite (MAC) for liquid intake, distribution, and retention. The multifunctional absorbent material incorporates at least three structural elements for liquid distribution and retention.

In one aspect, the absorbent structure and method of the present invention provide a multifunctional absorbent composite (MAC) for liquid intake, distribution, and retention. The multifunctional absorbent material composite incorporates at least three structural elements for liquid distribution and retention.

A first structural element of the present invention provides an interconnected capillary or channel system (ICS) created by a wettable lamellae or foams network. The lamellae or foams network includes a web capable of uptaking and efficiently spreading or moving the liquid up to a higher elevation.

1
A second structural element of the present invention provides a retention material including a superabsorbent material (SAM) located in direct physical contact with the interconnected capillary system in such a way that it can receive liquid efficiently from the interconnected capillary system and, by doing so, with subsequent swelling, does not destroy the adjacent capillary system or adversely affect the transfer of liquid to the retention layer. The multi functional absorbent material structure and method of the present invention attach the superabsorbent material to the surface of the interconnected capillary system. Alternatively, the multi functional absorbent material structure and method of the present invention embed the superabsorbent material within the interconnected capillary system only on one side of the web leaving the other side substantially free. In any case, a significant portion of the wicking layer is undisturbed by the swelling of the retention material. The superabsorbent material can be used in different physical forms including regular particulates, film, fibers, foam, and the like.

A third structural element of the present invention provides bonds, part of which are water resistant, combining the web within the interconnected capillary system and joining the interconnected capillary system with the superabsorbent material. Mechanical, electrical, or chemical means, or combinations of mechanical, electrical, or chemical means are used to create these bonds of the third structural element of the present invention.

The multi functional material of the present invention provides one integral layer or a plurality of layers placed one upon another. Optionally, the layers can be attached together permanently with mechanical, chemical, or other means.

The multi functional absorbent structure of the present invention exhibits superior liquid wicking and retention charac-

teristics, thereby providing advantages for use in absorbent personal care products. The multi functional absorbent structure and method of the present invention have two distinct functionalities, i.e., liquid transport by wicking and liquid retention by absorption. The multi functional absorbent structure and method of the present invention transport fluid effectively in the absorbent product, have the ability to wick liquid against gravity when the structure is placed in a vertical position, and retains the wicked fluid at a higher location in the structure relative to the point at which liquid contacts the structure.

Absorbent polymeric materials exhibiting liquid retention by absorption are available, but these materials have poor liquid transport properties and, in fact, can impede the transport of fluid by altering the capillary structure essential for liquid transport. Materials for wicking liquid also are available, an example of which are the cellulosic materials UnCreped Through-Air Dried (UCTAD) made by the wet forming approach. However, the absorbent capacity of such liquid transporting materials can be limited, and in some cases, these materials do not serve the preferred liquid retention function of the structure and method of the present invention.

Additionally, the multi functional absorbent structure and method of the present invention has good mechanical integrity in both the wet and dry state and is thin and flexible for effective use in an absorbent product.

The multi functional absorbent structure and method of the present invention make a superior multi functional absorbent structure which combines liquid retention with liquid transport. The multi functional absorbent structure and method of the present invention combine materials with good liquid retention properties with materials having good liquid transport properties. In one aspect, the multi functional absorbent structure

and method of the present invention combine superabsorbent material with UCTAD materials. To combine these materials and make the absorbent structure, the superabsorbent material of the structure and method of the present invention is combined with the UCTAD material using suitable bonding mechanism. The multi functional absorbent structure and method of the present invention combine the superabsorbent material and UCTAD in a manner which promotes the effective movement of liquid using the UCTAD layer and transfer of the liquid to the superabsorbent material.

The mechanism of bonding the UCTAD and superabsorbent material in the present invention provides for good wet and dry integrity and does not adversely impact the transfer of liquid from UCTAD to superabsorbent material.

The superabsorbent material remains in contact with UCTAD even after it begins to swell, and the delamination from UCTAD is avoided that would occur because of the large increase in superabsorbent dimensions and the consequent disturbance in bonding between the superabsorbent and UCTAD on swelling. Such a delamination would not only adversely impact the mechanical integrity of the structure but it would also prevent effective transfer of liquid from the UCTAD to the superabsorbent material as the contact between the superabsorbent and UCTAD would be disturbed. The multi functional absorbent structure and method of the present invention use several approaches to combine the UCTAD and superabsorbent material utilizing physical and chemical forces.

In one aspect, the multi functional absorbent structure and method of the present invention use a bonding agent to combine the UCTAD and superabsorbent material. The bonding agent used in the multi functional absorbent structure and method of the present invention maintains the effective contact between the two materials in the dry as well as wet state and also does not

adversely impact liquid movement between the two materials. The bonding agent in the present invention has the ability to bond the superabsorbent material to UCTAD and to maintain the bond as the superabsorbent material swells and further allows The multi functional absorbent structure and method of the present invention liquid transport across the interface formed by the bonding agent between the superabsorbent material and UCTAD.

The multi functional absorbent structure and method of the present invention were developed empirically. Laminates of UCTAD and superabsorbent materials were made, and the absorbent properties were evaluated. It was found that the desired liquid transport and retention characteristics were obtained only in some specific cases. The multi functional absorbent structures were examined by a technique using microscopy and image analysis, and the intimacy of contact between the superabsorbent material and UCTAD were found to determine the effectiveness of the absorbent in transporting and retaining liquid.

An example of the multi functional absorbent laminates formed are laminates of UCTAD and superabsorbent material bonded using polyhydroxyalkanoate or poly(lactic)acid as the bonding agent. The polyhydroxyalkanoate or poly(lactic)acid content varies, and the contact between the superabsorbent material and UCTAD is quantified by a parameter termed as the Contact Intimacy Ratio (CIR). The technique to determine the Contact Intimacy Ratio is described in this detailed description herein below.

It was found that the CIR has a strong positive correlation to the absorbent performance as measured by the Absorbent Capacity at a height of 15 cm when the absorbent laminate is tested using a vertical wicking test as described in the methods section. This correlation is clearly observed in comparing the CIR numbers and Absorbent Capacity for samples BK-7 through BK-11 as set forth in the actual Examples described in this detailed

description herein below. The correlation coefficient is 0.973. Sample BK-7 is an example of this invention with an Absorbent Capacity of 5.4 g/g, and samples BK-8 through BK-11 have lower absorbent capacity.

5 In another embodiment of the multi functional absorbent structure of the present invention, a hydrophilic hot melt adhesive is used to achieve the bonding of the UCTAD to the superabsorbent material and create the multi functional absorbent structure.

10 In another embodiment of the multi functional absorbent structure of the present invention, having an Absorbent Capacity of 7.5 g/g., a water soluble polymer Kymene 557LX is used as the bonding agent, and further used a mixture of superabsorbent and fluff pulp mixture. In this embodiment, the multi functional
15 absorbent structure is not composed of just the UCTAD layer with SAM and a bonding agent as the other examples. It also has fluff pulp.

The novel multi functional absorbent structure of the present invention is a laminate composed of (i) a superior liquid transport layer (UCTAD) and (ii) a superior liquid retention material (superabsorbent material) combined together using (iii)
20 a specified bonding agent combined together in a manner which provides both the liquid transport and liquid retention functions in combination which has been found to provide unexpected preferred advantages in the performance of the novel laminate of the
25 present invention.

The novel multifunctional absorbent structure of the present invention is a laminate combined together in a manner to obtain a novel intimate contact to achieve the preferred liquid transport
30 and liquid retention functions.

The multi functional absorbent structure of the present invention has good wet and dry mechanical integrity and is thin

and flexible, thereby providing preferred features for use in absorbent products.

The composite absorbent structure of the present invention provides a first wicking layer including wettable lamellae or foams, wherein the first wicking layer exhibits a vertical liquid flux rate value at a height of about 15 centimeters of at least about 0.08 grams of liquid per minute per gram of absorbent structure per meter length of the first wicking layer; a second retention layer including a hydrogel-forming polymeric material; and a bonding agent for bonding the first wicking layer and the second retention layer to form a composite absorbent structure having a minimum contact intimacy ratio for providing a liquid transport function and a liquid retention function such that the first wicking layer and the second retention layer are combined together in a manner to obtain a contact to achieve liquid transport and liquid retention functions at a length of at least about 15 centimeters, a saturated capacity of at least about 5 grams of liquid per gram of composite absorbent structure, and an Absorbent Capacity at 15 cm of at least about 5 grams of liquid per gram of second retention layer. Preferably, the first wicking layer includes wettable lamellae or foams. Preferably, the hydrogel-forming polymeric material includes a superabsorbent. In one aspect, the bonding agent includes a polyhydroxyalkanoate. In one aspect, the bonding agent includes poly(lactic)acid. In one aspect, the bonding agent includes a hydrophilic hot melt adhesive. In one aspect, the bonding agent includes a polyaminoamide epichlorohydrin wet strength resin. In one aspect, the first wicking layer exhibits a vertical liquid flux rate value at a height of about 15 centimeters of at least about 0.1 grams, preferably at least about 0.12 grams, of liquid per minute per gram of first wicking layer per meter length of cross-sectional width of the first wicking layer. In one aspect,

the first wicking layer exhibits a vertical liquid flux rate value at a height of about 5 centimeters of at least about 0.4 grams, preferably at least about 0.6 grams, of liquid per minute per gram of first wicking layer per meter length of cross-sectional width of the first wicking layer. In one aspect, the wettable cellulosic fibers exhibit a wet curl value between about 0.11 to about 0.25, the first wicking layer exhibits a vertical liquid flux rate value at a height of about 5 centimeters of at least about 0.4 grams of liquid per minute, the first wicking layer exhibits a wicking time value of less than about 3.5 minutes, and the first wicking layer, having a basis weight of about 200 grams per square meter, exhibits a dry tensile strength at least about 100 N of force per meter of first wicking layer width and a wet tensile strength at least about 50 N of force per meter of first wicking layer width, wherein the fibers are present in the first wicking layer in an amount of from about 50 to about 100 weight percent, based on the total weight of the absorbent structure, and the first wicking layer exhibits a density between about 0.08 to about 0.5 grams per cubic centimeter.

In one aspect, the absorbent structure has a wet geometric mean breaking length of at least 5 meters and a dry geometric mean breaking length of at least 50 meters, and the first wicking layer exhibits a vertical liquid flux rate at a height of about 5 centimeters of at least about 0.4 grams of liquid per minute, such that the first wicking layer exhibits a wicking time of less than about 3.5 minutes, and the first wicking layer, has a basis weight greater than 100 grams per square meter and less than 300 grams per square meter.

$$\text{Geometric Mean Breaking Length} = (\text{MD} \times \text{CD})^{1/2} / \text{BW}$$

where MD is the tensile strength of the web in the machine direction and CD is the tensile strength of the web in the cross-machine direction and BW is the basis weight, with all units being chosen to result in meters of breaking length. Wet breaking length is measured after the specimen is submerged in 0.9% saline for 10 to 12 seconds.

In one embodiment of the present invention, the multifunctional material of the present invention material is obtained by providing SAM particles of 25 μm to 300 μm in size, suspended in a stream of air. Alternatively, gravity force also can be used. The SAM particles in air suspension are blown into the sheet. Cellulose fibers are wet-laid using an uncreped through-air dried-type tissue machine. Embedding of SAM particles can be accomplished either at the end of the through-air drying step, or as a separate step on the machine or off the machine.

In the first approach, on the tissue machine, the through-air drier is sectioned such that the last part prior to the sheet leaving the drier provides a slight vacuum (-0.5 to -5 in. (-1 cm to 13 cm) of water). The air/SAM suspension is blown into that section.

In the second version, a separate vacuum box is provided after the drier. The material passes above it, and the suspension is blown into the sheet.

In the third version, the SAM embedding takes place during rewinding or converting.

It has been found that the described material is surprisingly thin and flexible.

It has been found that the multifunctional material of the present invention provides very high integrity both in dry and wet conditions.

It has been found that the multifunctional material of the present invention provides surprisingly high efficiency in

uptaking, transporting, and permanently locking the fluid,
thereby utilizing most of its mass.

It has been found that the multifunctional material of the
present invention can be rolled up easily and unwound conve-
niently for the production of various absorbent articles, e.g.,
such as sanitary napkins and incontinence devices.

The multifunctional material of the present invention is
particularly preferred for making products thinner than currently
available absorbent articles containing thick, low-integrity pads
of fluff/superabsorbent material composites.

The multifunctional material of the present invention
provides for better utilization of the absorbent mass compared to
currently available absorbent structures. The increased levels
of utilization of the absorbent mass are attributable to a more
uniform distribution of liquid within the multifunctional mate-
rial of the present invention.

Another extremely useful feature of the multifunctional
material of the present invention includes a high integrity of
the whole absorbent system of the present invention during use in
a disposable absorbent product. This integrity is of significant
advantage over currently available absorbent articles which have
weak absorbent cores.

The present invention provides a multifunctional material
combining a liquid distributing function with a liquid retention
function. The multifunctional material of the present invention
includes preferably a cellulose-based sheet having embedded in it
superabsorbent material (SAM) particles.

The multifunctional material of the present invention
provides features, on a test basis using liquid of 0.9% sodium
chloride, listed as follows.

1. A 15 centimeter vertical wicking flux of the material no lower than 0.06 grams of liquid wicked per minute per gram of material per meter of sample length.

2. A saturation of the material at 15 cm elevation (15-cm vertical wicking) no lower than 5 grams of liquid/gram of material after 60 min.

3. A permeability of the material measured horizontally under 0.3 psi mechanical load no lower than 100 Darcy after 60 minutes.

A novel structural analysis method has been developed to be used for the multifunctional composites of the present invention. The method measures "closeness" or intimacy with which layers touch each other. The term "Contact Intimacy Ratio" (CIR) is used to describe the novel development. A pictorial, idealized model of a wicking/retention/wicking composite, e.g., an UCTAD / SAM / UCTAD composite was drawn, and an equation developed. The term "UCTAD" is an acronym for uncreped, through-air dried (UCTAD). The equation also can be used for a two layer wicking/retention composite.

Referring now to Figure 1, a graphical depiction is shown of the Contact Intimacy for the model of an UCTAD / SAM / UCTAD composite model in a projected relationship to the appearance of a cross section 2 of the idealized model of an UCTAD / SAM / UCTAD composite model.

An embedding and cross-sectioning technique has been developed for analyzing the composite absorbent structures of the present invention.

Software has been written and tested for auto-stage, automatic image analysis of scanned visual images of cross sections of the composite absorbent structures of the present invention.

Parameters from CI have been shown to correlate well $R = 0.97$) with absorption performance for various particulate composites; and rank appropriately various fibrous SAM composites.

It is preferred that the first wicking layer of the present invention can quickly and effectively transport liquid from a centralized liquid insult location to distant locations within the first wicking layer or within a disposable absorbent product. With such an ability, the first wicking layer of the present invention is particularly useful, for example, as a liquid distribution material within a disposable absorbent product.

Distribution must take place at an acceptable speed such that the target insult area, the crotch area, is ready for the next insult. The time between insults can range from just a few minutes to hours, depending on the age of the wearer.

To achieve a preferred transportation function, a distribution layer must have a high capillary tension value. Capillary tension in distribution and other materials not containing superabsorbents is measured simply by the equilibrium vertical wicking height of an aqueous saline solution containing 9.0 g/l sodium chloride per liter, not by the test method given for materials containing superabsorbents. A successful distribution layer must have a capillary tension greater than the adjacent material from which it receives liquid and preferably a capillary tension of at least about 15 cm. Because of an inverse relationship between capillary tension and permeability, a high capillary tension provides the distribution layer with a low permeability.

In the case of an infant's diaper, for example, it is preferred that about 8 grams of a distribution material having a basis weight of about 200 grams per square meter would be capable of being able to transport about 100 milliliters of liquid, and preferably about 120 milliliters of liquid, within about 30

minutes to a distance of up to about 15 centimeters away from a centralized liquid insult location.

One liquid transport property preferred of the first wicking layer of the present invention is that the first wicking layer exhibits a Vertical Liquid Flux rate, at a height of about 15 centimeters, preferably of at least about 0.08 grams of liquid per minute per gram per square meter of first wicking layer, more preferably of at least about 0.003 g/(min*gsm*inch), and up to about 0.1 g/(min*gsm*inch). The Vertical Liquid Flux rate can be determined as set forth in the Vertical Liquid Flux rate test procedure as set forth in U.S. Patent No. 5,843,852 which is hereby incorporated by reference and included herein as if set forth verbatim. The term "g/min*G.M.*inch" refers to grams of liquid per minute per gram per square meter of first wicking layer per inch of cross-sectional width of the absorbent structure. As used herein, the Vertical Liquid Flux rate value of a first wicking layer is meant to represent the amount of liquid transported across a boundary a specified vertical distance away from a centralized liquid insult location per minute per normalized quantity of the absorbent structure. The Vertical Liquid Flux rate, at a height of about 15 centimeters, of a first wicking layer may be measured according to the test method described herein.

Another liquid transport property preferred of the first wicking layer of the present invention is that the absorbent structure exhibits a Vertical Liquid Flux rate, at a height of about 5 centimeters, preferably of at least about 0.01 g/(min*G.M.*inch), more preferably of at least about 0.015 g/(min*G.M.*inch), most preferably of at least about 0.02 g/(min*G.M.*inch), and up to about 0.5 g/(min*G.M.*inch). The Vertical Liquid Flux rate, at a height of about 5 centimeters, of

a first wicking layer may be measured according to the test method described herein.

Another liquid transport property preferred of the first wicking layer of the present invention is that the first absorbent layer exhibits a Wicking Time value of a liquid to an elevation of 15 centimeters of preferably less than about 3.5 minutes, more preferably less than about 3 minutes, and most preferably less than about 2.5 minutes. As used herein, the Wicking Time value of an absorbent structure is meant to represent the time needed to transport a liquid a specified vertical distance away from a centralized liquid insult location. The Wicking Time value of a liquid to an elevation of 15 centimeters for a first wicking layer may be measured according to the test method described herein.

The first wicking layer of the present invention should have a density such that the first wicking layer exhibits the preferred liquid transport properties described herein. The density of a first wicking layer determines the porosity, permeability, and capillary structure of the first wicking layer. If the density of the first wicking layer is too high, the capillaries of the first wicking layer will be too small such that the capillaries provide a relatively high capillary tension force but, because of the relatively small capillaries, the permeability of the first wicking layer will be relatively low. If the permeability of the first wicking layer is relatively low, the first wicking layer will transport only relatively small amounts of liquid so that the vertical liquid flux rate of the first wicking layer is relatively low at each of about 5 centimeters and of about 15 centimeters of height from a source of liquid.

If the density of the first wicking layer is too low, the permeability of the first wicking layer is relatively high. The capillaries of the first wicking layer are relatively large such

that the capillaries provide relatively low capillary tension force providing the first wicking layer is unable to transport liquid quickly to relatively high elevations such as about 15 centimeters of height from a source of liquid. Such a first wicking layer has a relatively high vertical liquid flux rate at a height of about 5 centimeters of height from a source of liquid, but the liquid will move slower and slower, or stop altogether, the higher the front of the wicked liquid. The vertical liquid flux rate of the first wicking layer is relatively low at about 15 centimeters of height from a source of liquid.

Depending on the stability of the capillary structure of a first wicking layer, the density of the first wicking layer may change as a liquid enters into the capillary structure of the first wicking layer. The structural stability of the first wicking layer depends on such factors as the stability, as measured by shape, curl, stiffness, or resiliency, of the fibers in the first wicking layer as well as the stability of the first wicking layer as a whole. Structural changes of the first wicking layer are more likely if the first wicking layer is under a stress or pressure as, for example, when the first wicking layer is used in a diaper being worn by a human.

It is preferred that the density of the first wicking layer does not change substantially when the first wicking layer absorbs a liquid or otherwise becomes wet or is under a stress or pressure and/or that the first wicking layer substantially recovers its density after the liquid or stress or pressure is removed from the absorbent structure. The stability of the density of the first wicking layer may be quantified by the difference in densities exhibited by the first wicking layer when different loads, such as each of loads of about 1000 Pa to 2000 Pa, are applied to the first wicking layer. If the difference in

the densities exhibited by the first wicking layer at the different loads is relatively small, the first wicking layer is considered to be structurally stable. Another method of characterizing the structure of a first wicking layer is by measuring the void volume of the first wicking layer. The first wicking layer has a basis weight of from about 35 to about 300 G.M., or more preferably from about 80 to about 200 G.M., a density of between about 0.08 and about 0.5 g/cc, and a permeability between about 50 and about 1000 Darkest.

It is preferred to use little first wicking layer in the disposable absorbent product, and preferably the first wicking layer of the present invention exhibits a total weight less than a certain number of grams, e.g., depending on the particular disposable absorbent product.

The first wicking layer of the present invention should exhibit sufficient dry and wet tensile strengths such that the first wicking layer maintains its structural integrity during manufacturing, handling, and use. The dry and wet tensile strengths of wet-laid first wicking layers are provided for a first wicking layer of the present invention. It is preferred that a first wicking layer of the present invention, having a basis weight of about 200 grams per square meter, exhibits a dry tensile strength at least about 2000 N/m of force of first wicking layer width, preferably at least about 3000 N/m of force per inch of first wicking layer width, and more preferably at least about 4000 N/m of force per inch of first wicking layer width. It is preferred that a first wicking layer of the present invention exhibits a wet tensile strength at least about 200 N/m of force of first wicking layer width, preferably at least about 400 N/m of force of first wicking layer width, and more preferably at least about 800 N/m of force of first wicking layer width.

In one embodiment, a wet strength resin is added to the

fibers forming a first wicking layer to improve the wet strength properties of the first wicking layer. The wet strength resin is sufficiently hydrophilic so that the resin does not adversely affect the wettability of the fibers.

5 In one embodiment, the first wicking layers of the present invention are prepared by a wet-laying process. The wet laying process provides a first wicking layer which exhibits sufficient dry and wet tensile strengths. In contrast, an air-laying process results in a first wicking layer that will not exhibit
10 sufficient dry and wet tensile strengths. However, by using wet strength resins, binder fibers, or by the careful selection of fibers used to prepare the first wicking layer, an air-laid first wicking layer is prepared that exhibits the properties preferred in the present invention.

15 Binder fibers can be used in the present invention.

Preferably, the process used to prepare the first wicking layer is an uncreped, through-air dried (UCTAD) process. The uncreped, through-air dried (UCTAD) process is set forth in U.S. Patent No. 5,843,852 which is hereby incorporated by reference
20 and included herein as if set forth verbatim.

It has also been discovered that the liquid transport properties of a first wicking layer of the present invention may be improved if the first wicking layer is a composite including multiple layers or sections of separate first wicking layers as
25 compared to a unitary absorbent structure. As such, instead of preparing a unitary absorbent structure of a particular size or dimension, it may be desirable to prepare separate absorbent structure layers or sections that, when attached or combined with each other, form a composite that is substantially the same size
30 and/or dimensions as the unitary absorbent structure. As an example, instead of preparing a unitary absorbent structure having a basis weight of about 200 grams per square meter, it may

be desirable to prepare four separate absorbent structure layers each having a basis weight of about 50 grams per square meter. If effectively attached or combined with each other, the four smaller absorbent structure layers will form a composite that has a basis weight of about 200 grams per square meter and otherwise substantially has the same size and/or dimensions as the unitary absorbent structure.

The novel method Contact Intimacy in UCTAD/SAM Composites method to measure structure in UCTAD/SAM Composites includes a structural analysis method specific to UCTAD/SAM composites. The method successfully correlates with 15-cm vertical absorption capacity on UCTAD/SAM samples and ranks the fibrous SAM composites appropriately.

Figure 1 shows an original concept diagram and equation for normalized Contact Intimacy using means and standard deviation of a location histogram (X-coordinates) within each field of view. The Figure 1 equation represents only one form that applies to the geometry of UCTAD / SAM / UCTAD. The equation is modified to accommodate UCTAD / UCTAD / SAM, or just UCTAD / SAM.

A plot of 4-cm Absorption Capacity, as the Y-variable, versus the standard deviation in SAP location as the X-(independent) variable results in a correlation coefficient (0.97) which is actually negative, revealing an inverse trend such that absorption physically is better when SAM particles are more closely spaced or closer together. The more positive the CI value, the better the intermixing, and hence, the better the intimacy of contact.

The preparatory method for the cross-sections now will be described. Calco Oil Red YM liquid dye (BASF, New Jersey, USA) was used to counter-stain the medium, thereby to provide an intermediate shade of gray for image analysis.

The following procedure provides for embedding and microtomy of superabsorbent particle - tissue composites for light microscopy.

1. Cut out a segment of sample to fit within 1 to 2 millimeters of the mold dimensions. The mold size and design should be such that the final 15 μ m thin section is 1 cm wide by at least 4 cm long with the sample reasonably centered in the cross-section. For example, the mold can be a rectangular clear polystyrene container [inside dimensions = 30 mm (VV) X 72 mm (L) X 12 mm (H)], and the cut sample dimensions can be 29 mm X 70 mm.

2. Glue a 3 mm thick [-60mm (L) X -13 mm (W)] plastic spacer to the bottom, center of the mold to keep samples from settling to the bottom of the mold. Do not use wood splints which tend to out-gas and release air bubbles which float up into the sample.

3. Epofix (Struers, Copenhagen, DM) epoxy preparation:

A. Dispense 30 grams of resin into a disposable container.

B. Add 6 drops of Calco oil red YM liquid (BASF, New Jersey, USA). Dye is added to the resin to give the final thin section an optical density intermediate between the pulp fibers which are darker and the superabsorbent particles which are brighter.

C. Mix thoroughly for 2 minutes.

D. Place under vacuum for at least 1 hour to de-gas the resin.

E. Add 3.6 grams hardener (ratio by weight = 8.33:1 R:H).

F. Mix thoroughly for 2 minutes.

G. Pour part of mixture into mold to 3/4 full and place mold and remaining epoxy under vacuum for no longer than 15 minutes. Mixed epoxy has a pot life of about 30 minutes before it thickens significantly.

H. Gently lower sample into epoxy and let it fully saturate.

I. Add extra epoxy around the edges of the sample until fully saturated and completely covered.

5 J. Let sample set at room temperature overnight for complete curing.

10 4. Trim the cured block by cutting off a 5 mm thickness from the four sides and ends to expose the embedded sample and ensure any compressed edges of the sample compressed by trimming with scissors have been removed.

5. Trim away the base of the mold to remove the polystyrene layer, as this will interfere with cutting undistorted sections in the microtome.

15 In steps 4 & 5, best results were obtained by cutting with a band saw followed by flattening the cut with a belt sander.

6. A block is produced having dimensions of 2 cm (W) X 6 cm (L) X 1 cm (H). Two thin-section samples are obtained from each block by cutting the two opposing 1 cm X 6 cm faces with the microtome.

20 7. Microtomy of the block faces.

A 40° tungsten carbide knife set at the zero (recommended) position was used.

A. Mount block face securely with the longest dimension parallel to the direction of travel.

25 B. Plane off the block face at 50 μ m per pass and no more than 3 mm per second until entire surface is flat.

30 C. Remove 4 additional sections at 15 μ m per pass and 1.5 mm per second. Huffing the block face with a few short breaths prior to each pass will soften the superabsorbent particles (SAP) sufficiently to prevent them from fracturing when cut. Too much softening will compress the particles upon cutting, forming adjacent holes.

D. Repeat with the fifth section and hold the leading edge of the section taut with tweezers as it comes off to avoid wrinkling and curling.

8. Mounting thin-sections for microscopy and image analysis:

A. Place flat on a clean, dry microscope slide (1" X 3" are preferred) and trim off the leading and trailing ends with a razor blade.

B. Reposition the trimmed thin-section on the center of the slide in three drops of refractive index liquid (R.I. = 1.572 from R. P. Cargille Laboratories, Inc., Cedar Grove, NJ). Place two additional drops on top of the section.

C. Work out any trapped air bubbles with a clean, smooth probe while viewing under a low power stereo-microscope.

D. Cover with a 50 mm to 60 mm No. 1 ½ cover glass.

In the procedure for analyzing Contact Intimacy, the sample is illuminated by four low-angle incident flood lamps. The sample then is imaged with a 20 mm Leica Quantimet 970 Image Chalnicon scanner and a Leica Quantimet 970 Image Analysis System (Leica Corp., Deerfield Ill.)

A software routine for the Quantimet 970 Image Analysis System has been developed to automate the Contact Intimacy analysis. The routine "CONIM8" provides auto-stage motion from field to field, centering of the image within each field, and data extraction from location histograms to calculate several versions of Contact Intimacy. Optical and imaging conditions are listed directly as follows.

Cambridge Instruments QUANTIMET 970 QUIPS/MX: V08.00 USER :
ROUTINE: CONIM7 DATE: RUN: SPECIMEN:

NAME = CONIM7

DOES = SCANS SLIDE TO GET CONTACT INTIMACY OF SAM/UCTAD X-SECTNS.

BUT SLIDE IS POSITIONED BY ST6 ON LEFT UCTAD LAYER, AND REGIONS
ARE CHOSEN MANUALLY. ALSO GETS THE ABS CONTIN PER LAYER, AS

5 POST-ANALYSIS CALC.

AUTH = B.E. KRESSHER /

DATE = 2 JULY 1997

COND = 2X OBJ ON OLYMP SCOPE; TRANS LIGHT; VHDF; LOW-MAG CONDENS
SCANNER ROATED 90 DEG COUNTER-CLOCKWISE; IM AMP AT 1.0

10 Enter specimen identity

Scanner (No. 2 Chalnicon LV= 3.99 SENS= 1.46 PAUSE)

Calibrate User Specified (Cal Value = 9.135 microns per pixel)

SUBRTN STANDARD

Load Shading Corrector (pattern - CONIM3)

15 CONTIM := 0.

TOTFIELD5 := 0.

LAYERS := 1.

LAYERS := 1.

HCOUNT := 0.

20 HMEAN := 0.

HSO := 0.

HMEDIAN := 0.

HSKEW := 10.

STGPERPX := 10.

25 A := 140.

A := 250.

For SLIDE = 1 to 1

STAGEX := 5000.

```

STAGEY      := 10000.

Stage Move (STAGEX,STAGEY)
Stage Scan ( X    Y
            Scan oriqin STAGEX STAGEY
5           Field size  3800.0 2000.0
            No of fields  15      1    )

FLAG        := 3.
Pause message

PLEASE POSITION THE SLIDE FOR ANALYSIS
10 Pause
For FIELD

Image Frame is Rectangle ( X: 48, Y: 187, W: 800, H: 324, )

Pause Message

DETECT LEFT FIBERS FOR STGE POSITIONING
15 Detect 2D ( Darker than 46, Delin PAUSE )
    Amend ( OPEN by 1 - Horizontally )
    Edit (pause) EDIT
    Amend ( CLOSE by 20 )
    Measure feature  AREA  X.FCP  Y.FCP  XCENTROID
20      into array FEATURE ( of 1000 features and 5 parameters )
    HMEAN := Field sum of FEATURE XCENTROID
    If HMEAN > A then
    DISTANCE := ( HMEAN - A ) % STGPERPX
    STAGEY   := STAGEY - DISTANCE
25 Stage move ( STAGEX,STAGEY)

```

```

Else
DISTANCE  := ( A - HMEAN ) % STGPERPX
STAGEY    := STAGEY + DISTANCE
Stage Move ( STAGEX,STAGEY)
5  Endif

Pause message

PLEASE DETECT SAM PARTICLES
Detect 2D ( Lighter than 58, Delin PAUSE )
Amend ( CLOSE by 1 )
10 Amend ( OPEN by 1 )
Amend ( CLOSE by 2 )
Pause Message

SELECT OTHER SAM, AND REMOVE DEBRIS...
Edit (pause) EDIT

15 Measure feature   AREA   X.FCP   Y.FCP   XCENTROID
      into array FEATURE ( of 1000 features and 5 parameters )
FEATURE XCENTROID := XCENTROID % CAL.CONST
Distribution of COUNT v XCENTROID (Units MICRONS )
      from FEATURE in HIST03 from 0. to 7700.
20      in 14 bins (LIN)

Pause Message

DETECT LEFT-SIDE FIBER LAYER (U1, S1)....
Detect 20 ( Darker than 48, Delin PAUSE )
Amend ( OPEN by 1 - Horizontally )
25 Pause message

```

SELECT LEFT-SIDE FIBER REGION....

Edit (pause) EDIT

Measure feature AREA X.FCP Y.FCP XCENTROID
 into array FEATURE (of 1000 features and 5 parameters)
5 FEATURE XCENTROID := XCENTROID % CAL.CONST

Distribution of COUNT v XCENTROID (Units MICRONS)
 from FEATURE in HIST01 from 0. to 7700.
 in 14 bins (LIN)

If LAYERS = 2, then

Pause Message

DETECT RIGHT-SIDE FIBER LAYER (U2, S2)....

Detect 20 (Darker than 48, Delin PAUSE)

Amend (OPEN by 1 - Horizontally)

Pause message

SELECT RIGHT-SIDE FIBER REGION....

Edit (pause)

Measure feature AREA X.FCP Y.FCP XCENTROID
 into array FEATURE (of 1000 features and 5 parameters)
FEATURE XCENTROID := XCENTROID % CAL.CONST

Distribution of COUNT v XCENTROID (Units MICRONS)
 from FEATURE in HIST02 from 0. to 7700.
 in 14 bins (LIN)

Endif

TOTFIELDS := TOTFIELDS + 1.

Stage Step

Pause Message

5 DO YOU WANT TO CONTINUE?...

Pause

Next FIELD

Next

Special Function # 5 : READ STATISTICS FROM HISTOGRAMS

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200

```

NUMERAIR      :- ( SAMMINUS - LEFTPLUS ) + ( RITEMINUS - SAMPLUS )
NUMERATR      := SAMMINUS - LEFTPLUS
DENOMIN       := ( LEFTMINUS + RITEPLUS )
DENOMIN       := LEFTMINUS + SAMPLUS
5  CONTIM      := ( - 10. ) % NUMERATR / DENOMIN

Print " "
Print "TOTFIELDS =" , TOTFIELDS , " OF HE16HT =" , I.FRAME.H %
CAL.CONST
Print " "
10 Print "CONTACT INTIMACY RATIO =" , CONTIM , " (MORE POSITIVE =
    BETTER ) "
Print " "
Print "ABS CONTACT INTIMACY {} =" , NUMERATR , " (MORE NEGATIVE =
    BETTER)"
15 Print " "
Print "CONTIM / INTERFACE PAIR () =" , NUMERATR / LAYERS , "
    (SMALLER - 9ETTER) Q
Print " "
Print " "
20 Print "CENTERING DISTANCE (pixels) =" , A
Print " "
Print " "
Print " "
Print Distribution ( HIST03, differential, bar chart, scale =
25 0.00)
Print "DISTRIB OF SAM LOCATION ()"
For LOOPCOUNT = 1 to 24
Print " "
Next
30 Print Distribution ( HIST01, differential, bar chart, scale =
    0.00 )

```

```

Print "DISTRIB OF LEFT UCTAD LAYER ()"
Print " "
Print " "
Print " "
5   If LAYERS = 2. then
Print Distribution ( HIST02, differential, bar chart, scale =
0.00 )
Print "DISTRIB OF RIGHT UCTAD LAYER ()"
Endif
10  For LOOPCOUNT = 1 to 35
Print
Next
END OF PROGRAM

```

15 The procedure for Absorbent Capacity is described herein below under the Test Method identified as "Absorbent Capacity Vertical Wicking Test." In the Absorbent Capacity Test procedure, the amount of fluid in a 4 cm slice that is 13-17 cm above the fluid reservoir level is measured as an indicator of wicking performance of the UCTAD / SAM composites of the present invention.

20 In one aspect, the present invention includes a composite absorbent structure providing a first wicking layer having preferred liquid transport properties in contact with a second retention layer having preferred liquid retention properties.

25 The second retention layer includes a hydrogel-forming polymeric material and exhibits an Absorbent Capacity at 15 centimeters of at least about 5 grams of liquid per gram of second retention layer.

30 In one aspect the second retention layer includes a super-absorbent material (SAM). By superabsorbent material is meant a polymer having an absorbent capacity of at least 10 grams of 0.9%

by weight of aqueous sodium chloride solution per gram of polymer.

As used herein, the term "superabsorbent material" refers to a water-swellaable, water-insoluble organic or inorganic material having an absorbent capacity of at least 10 grams of 0.9% by weight of aqueous sodium chloride solution per gram of polymer and capable of absorbing at least about 20 times its weight and, preferably, at least about 30 times its weight in an aqueous solution containing 0.9 weight percent of sodium chloride.

Organic materials suitable for use as a superabsorbent material of the present invention can include natural materials such as agar, pectin, guar gum, and the like, as well as synthetic materials such as synthetic hydrogel polymers. Such hydrogel polymers include, for example, alkali metal salts of polyacrylic acids, polyacrylamides, polyvinyl alcohol, ethylene maleic anhydride copolymers, polyvinyl ethers, hydroxypropyl cellulose, polyvinylmorpholinone, and polymers and copolymers of vinyl sulfonic acid, polyacrylates, polyacrylamides, polyvinyl pyridines, and the like. Other suitable polymers include hydrolyzed acrylonitrile grafted starch, acrylic acid grafted starch, and isobutylene maleic anhydride copolymers and mixtures thereof. The hydrogel polymers preferably are lightly crosslinked to render the material substantially water insoluble. Crosslinking may be by irradiation, or by covalent, ionic, Van der Waals, or hydrogen bonding. Preferred superabsorbent materials are shell crosslinked so that the outer surface or shell of the superabsorbent particle, fiber, flake, film, foam, or sphere possesses a higher crosslink density than the inner portion of the superabsorbent. The superabsorbent materials may be in any form suitable for use in absorbent composites including particles, fibers, flakes, films, foams, or spheres. In one preferred embodiment of the present invention, the superabsorbent material

includes particles of hydrocolloids, preferably an ionic hydrocolloid.

5 An example of superabsorbent material polymer suitable for use in the present invention is SANWET ASAP 2300 polymer available from Chemdal, a business having offices in Portsmouth, Va. Other suitable superabsorbents may include DOW DRYTECH 2035LD polymer obtained from Dow Chemical Co., a business having offices in Midland, Mich.; or FAVOR SAB 870M and FAVOR SAB 880 polymer available from Stockhausen, Inc., a business having offices in Greensboro, N.C.

10 As used herein, the term "fiber" or "fibrous" is meant to refer to a particulate material wherein the length to diameter ratio of such particulate material is greater than about 10. Conversely, a "nonfiber" or "nonfibrous" material is meant to refer to a particulate material wherein the length to diameter ratio of such particulate material is about 10 or less.

15 A wide variety of fibers are employed in the preparation of the first wicking layer of the present invention. Illustrative fibers include, but are not limited to, cellulosic fibers such as wood and wood products, e.g., wood pulp fibers; non-woody paper-making fibers from cotton, from straws and grasses, such as rice and esparto, from canes and reeds, such as bagasse, from bamboos, from stalks with bast fibers, such as jute, flax, kenaf, cannabis, linen and ramie, and from leaf fibers, such as abaca and sisal; and man-made fibers obtained from regenerated cellulose or cellulose derivatives, such as cellulose acetate. The first wicking layer of the present invention also can use mixtures of such materials, e.g., mixtures of one or more cellulosic fibers.

20 25 30 Other materials from which the first wicking layer may be made include non-cellulosic fibers such as wool, glass, or silk, synthetic fibers, woven fabrics, and nonwoven webs. For example, the distribution layer may be a nonwoven fabric layer composed of

a meltblown or spunbond web of polyolefin filaments. Such nonwoven fabric layers may include conjugate, biconstituent, and homopolymer fibers of staple or other lengths and mixtures of such fibers with other types of fibers. The first wicking layer also can be a bonded carded web, an airlaid web, a wetlaid pulp structure composed of natural or synthetic fibers, or a combination of a bonded carded web, an airlaid web or a wetlaid pulp structure composed of natural or synthetic fibers.

In one embodiment of the present invention, it is preferred that the fibers used to prepare a first wicking layer be wettable. As used herein, the term "wetable" is meant to refer to a fiber or material which exhibits a water in air contact angle of less than 90° , i.e., 0° to 90° . Preferably, the cellulosic fibers useful in the present invention exhibit a water in air contact angle between about 0° to about 50° and more preferably between about 0° to about 30° . Preferably, a wettable fiber refers to a fiber which exhibits a water in air contact angle of less than 90° , at a temperature between about 0°C and about 100°C , and preferably at typical in-use conditions, such as about 20°C to 40°C .

Suitable fibers are those which are naturally wettable. However, naturally nonwettable fibers also can be used. It is possible to treat the fiber surfaces by an appropriate method to render them more or less wettable. When surface-treated fibers are employed, the surface treatment is nonfugitive; that is, the surface treatment does not wash off the surface of the fiber with the first liquid insult or contact. A surface treatment on a nonwettable fiber is considered to be nonfugitive when a majority of the fibers demonstrate a water in air contact angle of less than 90° for three consecutive contact angle measurements, with drying between each measurement. When the same fiber is subjected to three separate contact angle determinations, and when

all three of the contact angle determinations indicate a contact angle of water in air of less than 90°, the surface treatment on the fiber will be considered to be nonfugitive. When the surface treatment is fugitive, the surface treatment will wash off from the fiber during the first contact angle measurement, exposing the nonwetable surface of the underlying fiber, and will demonstrate subsequent contact angle measurements greater than 90°.

Beneficial wettability agents include polyalkylene glycols, such as polyethylene glycols. The wettability agent is used in an amount less than about 5 weight percent, preferably less than about 3 weight percent, and more preferably less than about 2 weight percent, of the total weight of the fiber, material, or absorbent structure being treated.

The fibers are present in the first wicking layer of the present invention in an amount effective to result in the first wicking layer being able to transport a preferred amount of liquid under preferred conditions. The fibers are present in the first wicking layer of the present invention in an amount of from about 30 to about 100 weight percent, preferably from about 50 to about 90 weight percent, and more preferably from about 70 to about 90 weight percent, based on the total weight of the absorbent structure.

During processing or preparation, a cellulosic fiber often has a curl imparted to it such that the fiber is no longer straight and becomes shortened. Such a curl may be the result of either chemical or mechanical means. The curl of a fiber may be quantified by a curl value which measures the fractional shortening of a fiber because of kink, twists, bends, or a combination of kink, twists, and bends in the fiber. For the purposes of this invention, a fiber's curl value is measured in terms of a two dimensional plane, determined by viewing the fiber in a two dimensional plane. To determine the curl value of a fiber, the

projected length of a fiber as the longest dimension of a two dimensional rectangle encompassing the fiber, F, and the actual length of the fiber, L, are both measured. An image analysis method may be used to measure L and F. A suitable image analysis method is described in U.S. Patent 4,898,642, incorporated herein in its entirety by reference. The curl value of a fiber can then be calculated from the following equation:

(Eq. 1)
$$\text{Curl Value} = (L/F) - 1$$

Depending on the nature of the curl of a cellulosic fiber, such curl may be stable when the cellulosic fiber is dry but may be unstable when the cellulosic fiber is wet.

The cellulosic fibers useful in preparing the first wicking layers of the present invention have been found to exhibit a substantially stable fiber curl when wet. This property of the cellulosic fibers may be quantified by a Wet Curl value, as measured according to the test method described herein, which is a length weighted mean curl average of a designated number of fibers, such as about 4000, from a fiber sample. As such, the Wet Curl value is the summation of the individual wet curl values for each fiber multiplied by the fiber's actual length, L, divided by the summation of the actual lengths of the fibers. The Wet Curl value is calculated by only using the necessary values for those fibers with a length of greater than about 0.4 millimeter.

The cellulosic fibers useful in preparing the first absorbent layers of the present invention have been found to exhibit a Wet Curl value preferably between about 0.11 to about 0.25, more preferably between about 0.13 to about 0.22, and most preferably between about 0.15 to about 0.20. Cellulosic fibers exhibiting a suitable Wet Curl value have been found to result in a first

wicking layer exhibiting the preferred liquid transport properties. In contrast, cellulosic fibers not exhibiting a suitable Wet Curl value have been found not to result in a first wicking layer exhibiting the preferred liquid transport properties. As such, the Wet Curl value of a cellulosic fiber may be used to determine if the cellulosic fiber will be capable of being used to prepare a first wicking layer having the preferred liquid transport properties described herein.

If a mixture of two or more cellulosic fibers is used to prepare the first wicking layer of the present invention, the mixture of fibers should exhibit a Wet Curl value preferably between about 0.11 to about 0.25, more preferably between about 0.13 to about 0.22, and most preferably between about 0.15 to about 0.20.

Stiffer fibers preserve their shape, including curl, better in water than fibers which are not stiff. As such, stiffer fibers maintain the porosity of a first wicking layer when wet, thus making the wet first wicking layer more permeable to liquid. In addition, resiliency of the fibers is an advantage if the first wicking layer is exposed to any stresses. Resiliency of a fiber aids the fiber in recovering its original shape and the porous structure of the first wicking layer when the stress is removed. Such features are advantageous for maintaining the liquid transport properties of the absorbent structure.

The stiffness and resiliency of fibers are improved by crosslinking the fibers, e.g., such as by oxidation, sulfonation, heat treatment, irradiation, chemical crosslinkers, or by sizing the fibers with polymers such as starch or chitosan; by changing the supermolecular structure of the fiber, e.g., such as by treating the fiber with swelling agents, such as alkaline solutions, and subsequently deswelling the fiber; or by fractionating the source of the fibers so as to obtain pulp containing, for

example, a higher amount of coarser, stiffer fibers, such as latewood fibers from wood sources.

A stiffer fiber may require less curl to be useful in the present invention. For example, coarse latewood fibers often have a relatively low Wet Curl value. Yet, a first wicking layer prepared from a latewood-rich fraction from a softwood kraft may possess effective porosity, permeability, and density to exhibit preferred Vertical Liquid Flux rate values.

In one embodiment of the present invention, a source of fiber is fractionated to obtain fibers having preferred properties.

The presence of very small fiber, or fines, in the cellulosic fibers useful in preparing the first wicking layer of the present invention have been found to exhibit a negative effect on the liquid transport performance of the first wicking layer. As used herein, the term "fines" is intended to refer to very small fibers that have a length that is less than about 0.2 millimeter. The weight percent of fines in a fiber sample may be determined by using a fiber analyzer instrument such as the Fiber Quality Analyzer, OpTest Product Code DA93, available from OpTest Equipment Inc., Hawkesbury, Ontario, Canada, the same equipment used herein to measure the Wet Curl value of a fiber sample. It is believed that such fines decrease the porosity of the first wicking layer and retard the transport of liquid. As such, it is preferred that the amount of fines present in a first wicking layer of the present invention be minimized as much as possible. The weight percent of fines in a fiber sample is less than about 4, preferably less than about 2, and more preferably less than about 1 weight percent of the total weight of fibers in the fiber sample.

The cellulose fibers useful in preparing the first wicking layer of the present invention may be prepared by mechanical,

chemical, and thermal processes, and by combinations of mechanical, chemical, and thermal processes. Such methods are suitable as long as such methods result in the cellulose fibers exhibiting the properties described herein so that the first wicking layer prepared using such fibers exhibits the preferred liquid transport properties described herein.

One method of preparing the cellulose fibers useful in the present invention is to sulfonate the fibers. Such a process is described in U.S. Patent 5,522,967, issued June 4, 1996, to R. Shet, the disclosure of which is hereby incorporated herein in its entirety by reference.

Another method of preparing the cellulose fibers useful in the present invention is to heat treat the fibers, e.g., such as by way of example, as described in U.S. Patent 5,834,095 issued December 1, 1998 to J. Dutkiewicz et al.

Another method of preparing the cellulose fibers useful in the present invention is to treat the cellulose fibers with a basic solution to swell the cellulose fibers. The basic solution may be prepared using an alkali metal hydroxide material, such as sodium hydroxide. Any combination of treatment in a basic solution and time which is effective in preparing the fibers, without undesirable damage to the fibers, so that a first wicking layer prepared from the basic-treated fibers exhibits the preferred liquid transport properties described herein, is suitable for use in the present invention.

The cellulose fibers first are added to a basic solution, allowed to soak for a preferred amount of time, and then neutralized with an acid solution to a pH of about 7. The treated cellulosic fibers then are used to prepare an absorbent structure.

If sodium hydroxide is used to prepare the basic solution used to treat the cellulosic fibers, the basic solution has a

concentration of from about 50 to about 500 grams of sodium hydroxide per liter of water and preferably from about 100 to about 300 grams of sodium hydroxide per liter of water. The treatment time of the cellulose fibers is from about 1 to about 10 minutes.

It also has been discovered that, by using a steam explosion process for treating cellulosic fibers and by using appropriate treatment conditions, modified cellulosic fibers exhibiting preferred properties are prepared by an efficient and effective process.

Other methods of preparing the cellulose fibers for use in a first wicking layer of the present invention include oxidizing the cellulose. In addition, cellulose fibers prepared from one of the above-described methods may be mixed together with non-treated cellulose fibers, with cellulose fibers prepared from another one of the above-described methods, or other non-cellulosic fibers to form a blend of fibers that is useful in preparing the first wicking layer of the present invention.

The detailed description of the multi functional material of the present invention includes specific embodiments and applicable alternatives, ranges, and products for the structure and method of providing the multi functional material of the present invention.

Actual examples of the multi functional material (MAC) of the present invention were prepared with UnCreped Through Air Dried (UCTAD) basesheets serving as the interconnected capillary system (ICS) of the present invention and various superabsorbent material SAMs in the form of particulates or superabsorbent material SAM extenders. By CR designations is meant southern softwood kraft pulp made by Alliance Corporation. By HP designations is meant southern softwood kraft pulp made by Buckeye

Cellulose Company. Favor SAP 870 is a superabsorbent material manufactured by Stock hausen, Inc. of Greensboro, North Carolina.

The UnCreped Through Air Dried sheets were high flux distribution materials as well as highly permeable UnCreped Through Air Dried sheets made with Bleached Chem.-Thermal Mechanical Pulp (BCTMP).

The following Example I produced a multi functional material made by imparting superabsorbent material SAM particulates on UCTAD substrates.

EXAMPLE I

A multi functional material was produced by pressing Super-Absorbent Material (SAM) of the type Favor 880 having a particle size distribution of 300-600 microns in between layers of Un-Creped Through Air Dried (UCTAD) tissue having a composition of 50:50 CR1654/HP and a basis weight of 67 G.M. A bottom layer of UCTAD was embossed to form depressions in the sheet. The preferred amount of SAM then was placed into the depressions in an amount of 150-175 G.M. SAM. A second sheet of UCTAD was sprayed with a fine mist of water to achieve a moisture content of approximately 40% by weight. The wet layer of UCTAD then was placed on top of the UCTAD layer containing the SAM in the depressions. The structure then was pressed to form the bond between the two layers. The water was used to enhance bonding between the two sheets as hydro-bonding. The depressions containing the SAM protected the open areas in the UCTAD sheet from being pressed. The depressions protected the distribution material's ability to wick liquid. A MAC also was produced to contain an equivalent amount of SAM as compared to a diaper (>300 G.M.). Two layers of SAM were pressed in between three layers of UCTAD.

The MACs produced using the method of Example I were very thin materials having high SAM content by weight (> 50%). The materials of Example I were observed to have excellent intake, spreading, and capacity properties. The integrity of these MACs also was much better than the weak absorbent cores used in disposable absorbent products today.

The following Example II describes MACs for spreading and liquid retention ability.

EXAMPLE II

MACs were produced by imprinting SAM between layers of UCTAD, barrier tissue, and combinations of both. The process by which these materials were manufactured was produced by spreading SAM onto a bottom sheet of tissue. The bottom layer containing the SAM then was sprayed with a fine water mist. A top sheet of tissue was laid on the bottom layer, and the laminate was pressed to bond the two layers of tissue together forming a sandwich. These sandwiches were very thin and flexible. Combinations of these MACs included the following structures.

(1) UCTAD(67 G.M.) - SAM(120 G.M.) - UCTAD(67 G.M.). Total weight was 254 G.M.

(2) UCTAD(67 G.M.) - SAM(120 G.M.) - Barrier tissue(20 G.M.) Total weight was 207 G.M. By barrier tissue is meant pulp sheet of 20 G.M. basis weight.

(3) Barrier tissue(20 G.M.) - SAM(86 G.M.) - Barrier tissue(20 G.M.) Total weight was 126 G.M.

These MACs produced in Example II were found to be materials which transport and retain the liquid in the sample. The MAC using two layers of barrier tissue did not show any spreading

qualities when wetted. A commercial Gel-Lok (tissue/SAM/tissue sandwich composite) performed relatively poorly as well. The UCTAD was observed to be necessary in these MACs to spread the liquid in the sample more quickly so the SAM can lock it away.

5 The materials containing UCTAD showed excellent transporting and retention qualities even though they will not vertically wick liquid as well as the MACs described above as structures (1), (2), and (3).

10 The following Examples III-IV describe MACs made by combining UCTAD substrated into layers with SAM extenders.

EXAMPLE III

As control, three layers of 67 G.M. UCTAD (50/50 CR1654/HP) were produced.

<u>Time to</u>	<u>Pickup Rate</u>	<u>(x10⁻⁴ g/min*G.M.*inch)</u>	<u>Total Fluid</u>
<u>(g)</u> 10 cm, 28 sec	113		
15 cm, 1.7 min	37		app. 8

EXAMPLE IV

A mixture of curled CR55/Favor 870 was made into absorbent composition.

20 Three layers of 67 G.M. UCTAD (50/50 CR54/HP), with 2.1 g absorbent composition were placed between two of the layers.

<u>Time to</u>	<u>Pickup Rate</u>	<u>(x10⁻⁴ g/min*G.M.*inch)</u>	<u>Total Fluid</u>
<u>(g)</u> 10 cm, 1.7 min	49.5		8
15 cm, 15.5 min	15		25

EXAMPLE V

A mixture of 80/20 Rayon/Favor 870 was made into an absorbent composition.

Three layers of 67 G.M. UCTAD (50/50 CR54/HP), with 2.1 g absorbent composition were placed between two of the layers.

<u>Time to</u>	<u>Pickup Rate</u>	<u>(x10⁻⁴ g/min*G.M.*inch)</u>	<u>Total Fluid</u>
<u>(g) 10 cm, 1.7 min</u>	47		9
15 cm, 24 min	11		30

The following Examples VI-IX produced MACs with SAM particles embedded in tissue. In one series of experiments, the tissue was UCTAD web. It was possible to retain up to 45% of SAM in the web. Most of the SAM particulates were located on one side of the web so that the other side was substantially free of SAM to take advantage of liquid intake and transport functions of the interconnected capillary system created by the fiber network ICS of the present invention. The obtained materials were observed to be thin, flexible, and exhibited surprisingly strong attachment of SAP to the fibrous web. The MACs obtained this way were observed to have excellent liquid transport, i.e., intake, spreading, and wicking properties, because of high permeability, porosity, and stable capillarity. They were able to retain large amounts of liquid without run-off. Additional surprising effects were appearance, thinness, flexibility, and integrity of the material as a whole. No SAM was observed to be falling off. The MACs looked and felt the same as the UCTAD substrates without SAM.

In all the following Examples VI-IX, the lab-sized apparatus was used to fabricate MAC. The superabsorbent additive was "fines" Favor 870. The lab-sized device functioned as follows: The cellulose material was unwound onto a 25 cm wide wire con-

veyor moving at 244 cm/min. The conveyor belt traveled over a top of the vacuum box. The vacuum box was under negative pressure of approximately 500 pascals.

The particulate material was metered from a 15 cm wide vibrational feeder at 171 g/min onto the top of the cellulose material. The contact point of the particulate material with the cellulose material fell, where a 49 mm long slot was present in the vacuum box under the wire. The vacuum aided in the transfer and retention of the particulate material within the cellulose material.

Short samples of material were made. The excess of particulate material was shaken off of the cellulose material, and the retention of the particulate material was measured gravitationally.

Microscopic observations were conducted of the super-absorbent distribution in z-direction of the sheet. There was a gradient in the particle distribution throughout the thickness of the base material. One side of the material was essentially free of the SAM particles.

EXAMPLE VI

The base material was (50/50 CR1654/HP) UCTAD of 67 G.M. basis weight.

SAM Particle

<u>size, (μm)</u>	<u>BW, (G.M.)</u>	<u>SAM</u>
No SAP	19.79	0
90-150 μm	20.02	1.18%
75-90 μm	20.19	2.01%
75-90 μm	20.24	2.23%
53-75 μm	20.33	5.01%
38-53 μm	22.28	11.20%
38-53 μm	22.63	12.58%

EXAMPLE VII

The base material was 50/50 CR1654/HP UCTAD. The 13.3% retention of superabsorbent was obtained.

EXAMPLE VIII

5 The UCTAD made with mercerized LL-19 was used.

<u>Basis Weight, G.M.</u>	<u>% SAM</u>
48.6	21-30
92.2	9-13
218.7	7-8

EXAMPLE IX

	<u>Description</u>	<u>BW, G.M.</u>	<u>% SAM</u>
	BCTMP UCTAD 33 G.M.		
	2 No SAM, 960518	20.01	0
	3 ALL SIZES	27.66	27.67%
15	4 ALL SIZES	30.78	35.01%
	5 ALL SIZES	28.20	29.05%
	7 960528 all sizes	30.17	33.69%
	BCTMP, UCTAD 33 G.M.		
	10 No SAM	35.00	0
20	11 960611 all sizes	56.73	38.29%
	12 60612 all sizes	55.46	36.88%
	13 60612 all sizes	50.48	30.66%
	15 12 <38 - 53	52.37	33.16%
	16 12 <38 - 53	51.98	32.66%
25	BCTMP, UCTAD 40 G.M.		
	20 No SAM	40.95	0
	21 960611 all sizes	56.62	27.68%
	22 960619 all sizes	75.13	45.50%

30 By applying the SAM to various BCTMP materials, the retention of SAM from 27 to 45% was achieved.

EXAMPLE X

An UCTAD/Adhesive/Favor 880/Adhesive/UCTAD Material was prepared and identified as Sample BK-1 and Sample BK-2. Composites BK-1 and BK-2 were layered composites having a structure of UCTAD/Adhesive/Favor 880/Adhesive/UCTAD.

Referring now to Figure 2, the cross sectional configuration of Samples BK-1 and BK-2 is shown. A composite 10 has a first UCTAD layer 12 and a second UCTAD layer 14 on opposite sides a superabsorbent layer 16. Adhesive layers 17 and 19 secure the composite together.

The difference in the two composite samples BK-1 and BK-2 was only the type of adhesive used.

The process of making such structures included five steps. (1) spread five grams per square meter of adhesive material spread onto an UCTAD sheet; (2) formed a 160 gram per square meter uniform layer of particulate of Favor 880 on the top of the Adhesive/UCTAD sheet; (3) spread another 5 grams per square meter of adhesive material onto Favor 880/Adhesive/UCTAD; (4) covered an UCTAD sheet on the top Adhesive/Favor 880/Adhesive/UCTAD sheet; and (5) pressed the sheet by a nip roller at 40 pounds per linear inch.

The UCTAD tissue used in Example X had a basis weight of about 67 G.M. and a density of about 0.10 grams per cubic centimeter. This UCTAD tissue also had a vertical wicking flux of 0.0029 grams of fluid per gram of dry material per square meter per inch width per minute. This UCTAD sheet also was microstrained at 0.015 inches of depth using the microstaining process described in U.S. Patent No. 5,743,999.

The SAM used in Example X was a commercial polyacrylate superabsorbent designated as Favor 880 obtained from Stockhausen. The superabsorbent had a degree of neutralization of

about 70 mole percentage. Favor 880 had a particle size range from 150 to 850 microns for this Example X.

The adhesive used in Example X included two types of adhesive material. In BK-1, the adhesive designated as H2525A was obtained from the Ato-Findley company. In BK-2, the adhesive designated as NS5610 was obtained from National Starch Company.

Absorbent Capacity vertical wicking tests were carried out, and the results are shown in Table 1.

Table 1.

Sample	Liquid in Comp. (g/g) Ave.; St.Dev.		Saturation of Comp. (%)	Liquid in SAP (g/g) Ave.; St.Dev.		Liquid in UCTAD (g/g) Ave.; St.Dev.	
BK-1	8.5	0.8	44.3	12.1	0.4	4.7	1.1
BK-2	6.3	0.5	32.8	10.1	0.7	3.8	0.2

EXAMPLE XI

An absorbent composite sample BK-3 was prepared using an air-forming process with the capability to unwind materials from a roll and also spray additives to form the absorbent composite.

A 80 G.M. bonded carded web (BCW) made of polyethylene/polyester bicomponent fiber was unwound from a roll onto a forming wire equipped with vacuum to enable other materials to be added. 258 G.M. of cellulose fluff and 189 G.M. of polyacrylate superabsorbent were delivered through a nozzle located about 10 inches above the forming wire at a velocity of about 150 ft/sec. using air to transport the mixture. About 80 G.M. of polyacrylic acid solution (15 % solids content) was added through two atomizing nozzles located between the fluff/SAM nozzle and the forming wire. About 20 G.M. of crosslinking agent Kymene 557 LX (6.0% solids content) also was added through two atomizing nozzles located between the fluff/SAM nozzle and the forming wire. The

polyacrylic acid and Kymene spray nozzles were positioned to obtain a uniform coating of polyacrylic acid and Kymene on the cellulose fluff / superabsorbent particulates being added. Finally, a 70 G.M. uncreped through-air dried (UCTAD) cellulose sheet was unwound from a roll and layered onto the air-formed composite. The Kymene spray was used to crosslink the polyacrylic acid which bonds the cellulose and superabsorbent particles to the BCW and UCTAD layers to form the absorbent composite.

An absorbent composite Sample BK-4 was prepared using the same equipment setup as described for Sample BK-3. The following changes in composition were made for Sample BK-4 compared to Sample BK-3. The cellulose fluff used in Sample BK-4 was 188 G.M. The polyacrylic acid in the solution sprayed had a degree of neutralization of 20% sodium polyacrylate and also contained 2% by weight of ammonium zirconium carbonate. Kymene solution was not sprayed while making the composite.

Referring now to Figure 3, the cross sectional configuration of Samples BK-3 and BK-4 is shown. A composite 20 has a surge layer 22 and a UCTAD layer 24 on opposite sides a super-absorbent/fluff layer 26.

Absorbent Capacity vertical wicking tests were carried out, and the results are shown in Table 2.

Table 2.

Sample	Liquid in Comp. (g/g) Ave.; St.Dev.		Saturation of Comp. (%)	Liquid in SAP (g/g) Ave.; St.Dev.		Liquid in UCTAD (g/g) Ave.; St.Dev.	
BK-3	0.17	0.09	1.3	0.35	0.02	1.4	0.4
BK-4	0.76	0.30	5.7	0.45	0.17	2.1	0.4

EXAMPLE XII

An UCTAD/Danaklon/Favor 880/Danaklon/UCTAD Material was prepared and identified as Samples BK-7, BK-8, BK-9, BK-10, and BK-11. Composites BK-7, BK-8, BK-9, BK-10, and BK-11 were air-laid composites having a structure of UCTAD/Danaklon/Favor 880/Danaklon/UCTAD.

Referring now to Figure 4, the cross sectional configuration of Samples BK-7, BK-8, BK-9, BK-10, and BK-11 is shown. A composite 30 has a first UCTAD layer 32 and a second UCTAD layer 34 on opposite sides of a superabsorbent layer 36. Danaklon layers 37 and 39 secure are positioned between the UCTAD layers and the superabsorbent.

The process of making the structures for Samples BK-7, BK-8, BK-9, BK-10, and BK-11 included five steps: (1) formed an air laid Danaklon layer having a basis weight of Danaklon ranging from 0 to 80 grams per square meter on top of a UCTAD sheet; (2) formed a 150 gram per square meter uniform layer of particulate of Favor 880 on the top of the Danaklon/UCTAD sheet; (3) formed another air laid Danaklon layer having a basis weight of Danaklon ranging from 0 to 80 grams per square meter on top of the Favor 880/Danaklon/UCTAD sheet; (4) covered an UCTAD sheet on the top; and (5) pressed the composite by a Carver laboratory press (Model 2333) at a temperature of 150 °C under 15,000 psi for 30 seconds.

In the case of Example BK-0, no Danaklon staple fiber was used in that composite, and about 10 grams per square meter of adhesive material was spread onto the UCTAD and replaced Danaklon staple fiber. The BK-0 composite was pressed at room temperature under 15,000 psi for 10 seconds.

The UCTAD tissue used in Example XII had a basis weight of about 67 G.M. and a density of about 0.10 grams per cubic centimeter. This UCTAD tissue also had a vertical wicking flux of 0.0029 grams of fluid per gram of dry material per square meter per inch

width per minute. This UCTAD sheet also was micro-strained at 0.015 inches of depth.

The Danaklon used in Example XII was a commercial sheath/core polyethylene/polypropylene fiber having a diameter of 2.2 denier and a length of 6 mm manufactured by the Danaklon A/S Company.

The SAM used in Example XII was a commercial polyacrylate superabsorbent designated as Favor 880 obtained from Stockhausen. The superabsorbent had a degree of neutralization of about 70 mole percentage. Favor 880 had a particle size range from 150 to 850 microns for this Example XII.

Absorbent Capacity vertical wicking tests were carried out, and the results are shown in Table 3.

Table 3.

Sample	Liquid in Comp. (g/g) Ave.; St.Dev.		Saturation of Comp. (%)	Liquid in SAP (g/g) Ave.; St.Dev.		Liquid in UCTAD (g/g) Ave.; St.Dev.	
BK-0	7.3	0.6	42.9				
BK-7	5.4	0.5	31.8	8.4	0.9	2.2	0.9
BK-8	3.5	0.7	20.6	4.7	1.3	2.3	0.3
BK-9	2.9	0.5	17.0	2.9	0.7	2.9	0.4
BK-10	1.4	0.3	8.2	1.0	0.94	2.0	0.1
BK-11	0.8	0.1	0.5	8.4	0.04	1.6	0.2

EXAMPLE XIII

Composites Sample BK-30 and Sample BK-31 were single UCTAD tissues having SAM embedded in the tissue through an air laying process. The process of making such structures includes forming a superabsorbent uniform layer of particulate on an UCTAD sheet. While the air-laying of SAM is taking place a vacuum is applied on

the opposite side of the sheet causing SAM particles to embed themselves into the UCTAD tissue.

Referring now to Figure 5, the cross sectional configuration of Samples BK-30 and BK-31 is shown. A composite 40 has an UCTAD tissue sheet 42 embedded with superabsorbent particles 44.

The UCTAD tissue used in Example XIII had a basis weight of about 67 G.M. and a density of about 0.10 grams per cubic centimeter. This UCTAD tissue also had a vertical wicking flux of 0.0029 grams of fluid per gram of dry material per square meter per inch width per minute. This UCTAD sheet also was micro-strained at 0.015 inches of depth.

The SAM used in Example XIII was a commercial polyacrylate superabsorbent designated as Favor 880 obtained from Stockhausen. The superabsorbent had a degree of neutralization of about 70 mole percentage. Favor 880 had a particle size range from 0 to 250 microns for this Example XIII.

Absorbent Capacity vertical wicking tests were carried out, and the results are shown in Table 4.

Table 4.

Sample	Liquid in Comp. (g/g)		Saturation of Comp. (%)
	Ave.;	St.Dev.	
BK-30	4.7	1.2	63.5
BK-31	5.2	0.3	49.5

EXAMPLE XIV

Samples of UCTAD / SAM / UCTAD composites were submitted for determination of the Contact Intimacy as per the Contact Intimacy analysis method described herein above.

Image analysis was performed on a cross-section of the samples from Examples X, XI, XII, and XIII with the routine, "CONIM8-". Figure 6 shows a graphical depiction of the results.

In one embodiment of the present invention, a disposable absorbent product is provided, which disposable absorbent product includes a liquid-permeable top sheet, a back sheet attached to the top sheet, and an absorbent structure positioned between the top sheet and the back sheet wherein the absorbent structure is a composite absorbent structure as described herein.

One embodiment of the invention will be described in terms of the use of an absorbent structure in an infant diaper. It is to be understood that the absorbent structure is equally suited for use in other disposable absorbent products known to those skilled in the art such as training pants, feminine care products such as pads and tampons, incontinence products, and health care products such as capes or gowns.

Exemplary materials suitable for use as the top sheet are liquid-permeable materials, such as spunbonded polypropylene or polyethylene having a basis weight of from about 15 to about 25 grams per square meter. Exemplary materials suitable for use as the back sheet are liquid-impervious materials, such as polyolefin films, as well as vapor-pervious materials, such as microporous polyolefin films.

Disposable absorbent products, according to all aspects of the present invention, are subjected during use to multiple insults of a body liquid. Accordingly, the disposable absorbent products are capable of absorbing multiple insults of body liquids in quantities to which the absorbent products and structures will be exposed during use. The insults are separated from one another by a period of time.

Test Method - Wet Curl of Fibers

The Wet Curl value for fibers was determined by using an instrument which rapidly, accurately, and automatically determines the quality of fibers, the instrument being available from OpTest Equipment Inc., Hawkesbury, Ontario, Canada, under the designation
5 Fiber Quality Analyzer, OpTest Product Code DA93.

A sample of fibers was obtained from the fiber pulp used to prepare the sample hand sheet. The fiber sample was poured into a 600 milliliter plastic sample beaker to be used in the Fiber
10 Quality Analyzer. The fiber sample in the beaker was diluted with tap water until the fiber concentration in the beaker was about 10 to about 25 fibers per second for evaluation by the Fiber Quality Analyzer.

An empty plastic sample beaker was filled with tap water and placed in the Fiber Quality Analyzer test chamber. The <System
15 Check> button of the Fiber Quality Analyzer was then pushed. If the plastic sample beaker filled with tap water was properly placed in the test chamber, the <OK> button of the Fiber Quality Analyzer was then pushed. The Fiber Quality Analyzer then per-
20 forms a self-test. If a warning was not displayed on the screen after the self-test, the machine was ready to test the fiber sample.

The plastic sample beaker filled with tap water was removed from the test chamber and replaced with the fiber sample beaker.
25 The <Measure> button of the Fiber Quality Analyzer was then pushed. The <New Measurement> button of the Fiber Quality Analyzer was then pushed. An identification of the fiber sample was then typed into the Fiber Quality Analyzer. The <OK> button of the Fiber Quality Analyzer was then pushed. The <Options> button
30 of the Fiber Quality Analyzer was then pushed. The fiber count was set at 4,000. The parameters of scaling of a graph to be printed out may be set automatically or to preferred values. The

<Previous> button of the Fiber Quality Analyzer was then pushed. The <Start> button of the Fiber Quality Analyzer was then pushed. If the fiber sample beaker was properly placed in the test chamber, the <OK> button of the Fiber Quality Analyzer was then pushed. The Fiber Quality Analyzer then began testing and displayed the fibers passing through the flow cell. The Fiber Quality Analyzer also displayed the fiber frequency passing through the flow cell, which should be about 10 to about 25 fibers per second. If the fiber frequency is outside of this range, the <Stop> button of the Fiber Quality Analyzer should be pushed and the fiber sample should be diluted or have more fibers added to bring the fiber frequency within the preferred range. If the fiber frequency is sufficient, the Fiber Quality Analyzer tests the fiber sample until it has reached a count of 4000 fibers at which time the Fiber Quality Analyzer automatically stops. The <Results> button of the Fiber Quality Analyzer was then pushed. The Fiber Quality Analyzer calculates the Wet Curl value of the fiber sample, which prints out by pushing the <Done> button of the Fiber Quality Analyzer.

Water Retention Value

A 0.5 gram cellulosic fiber sample was obtained and dispersed into about 200 grams of deionized water using a Hobart Company Model N 50 blender set on the low speed setting for about 30 seconds. The cellulosic fiber/water suspension was transferred to a beaker and allowed to sit for about 16 hours. The supernate water was decanted and the cellulosic fibers were placed into a centrifuge (Dynac II by Clay Adams, Division of Becton Dickinson & Co., Model 5025, serial 012, cat. No. 0103) tube fitted with a screen. The cellulosic fibers then were centrifuged under a force of about 1000 times gravity for about 20 minutes. The cellulosic fibers then were removed from the centrifuge tube and weighed

(giving a wet weight W_w). The cellulosic fibers were then dried at about 105°C for about 120 minutes. The cellulosic fibers were then reweighed (giving a dry weight W_d). The Water Retention value then was calculated by subtracting the dry weight (W_d) from the wet weight (W_w) and then dividing that value by the dry weight (W_d). The Water Retention value were reported as the grams of water retained per gram of dry cellulosic fibers.

Preparation of Wet-Laid Hand Sheet

A 43 cm by 43 cm standard hand sheet having a basis weight of about 200 grams per square meter was prepared using a preferred fiber sample by using a 41 cm by 41 cm cast bronze wet-laid hand sheet former mold, available from Voith Corporation.

A British Disintegrator mixer, available from Testing Machines, Inc., was filled with about 2 liters of distilled water at room temperature (about 23°C) and about 37.3 grams of the fiber sample. The counter on the British Disintegrator was set to zero and the cover was placed on the British Disintegrator. The British Disintegrator was turned on until the counter runs to about 600. Alternatively, the British Disintegrator may be run for about 5 minutes. A bucket was filled with about 8 liters of distilled water. The contents of the British Disintegrator was then also poured into the bucket.

The hand sheet former, having a chamber about 30 cm deep, was filled partially with tap water to a depth of about 13 cm. The contents of the bucket were then poured into the hand sheet former chamber. A dedicated stirrer then was used to mix the suspension in the hand sheet former chamber. The stirrer was moved slowly up and down 6 times to cause small vortexes, but to avoid causing large vortexes, in the square pattern of the hand sheet former. The stirrer was then removed and the suspension was drained through the forming screen of the hand sheet former. The hand

sheet former was then opened and two layers of blotting paper were placed on the top of the hand sheet. A roller, having the equivalent of about 3.9 N/cm, was moved back and forth once on each of the left side, the right side, and the center of the formed hand sheet. The blotting paper, with the formed hand sheet attached, was then lifted off the forming screen. The blotting paper was then placed on a table such that the formed hand sheet faced upwards. An 46 cm by 46 cm, 4 mesh steel screen was placed on top of the hand sheet. The blotting paper, hand sheet, and screen were then flipped so that the screen was on the bottom and the blotting paper was on top. The blotting paper was then peeled off of the hand sheet, leaving the hand sheet on the screen. The edges of the hand sheet were fastened to the screen using binder clips. The hand sheet was left overnight to air-dry. The hand sheet, attached to the screen, was then placed in an oven and dried at about 105°C for about 60 minutes. The hand sheet then was removed from the oven and removed from the screen. The sheet then was equilibrated in a TAPPI conditioned room for 60 minutes. The sheet then was ready for evaluation for liquid distribution properties.

Thickness and Dry Density of an Absorbent Structure

From a hand sheet prepared according to the procedure described herein, a strip of sample hand sheet material having a width of about 5 cm and a length of about 38 cm was obtained by using a textile saw available, for example from Eastman, Machine Corp., Buffalo, New York. The sample strip was cut at least about 2.5 cm away from the edge of the hand sheet so as to avoid edge effects. The sample strip was marked in about 10 millimeter intervals using water-soluble ink.

To measure the bulk, i.e., thickness, of the sample strip, a bulk meter accurate to at least about 0.01 millimeter, such as a

bulk meter available from Mitutoyo Corporation, was used. A platen of about 2.54 cm diameter platen was used to measure the thickness, with the platen being parallel to the base of the thickness meter. The platen imposed 340 Pa pressure on the material of a sample strip. The thickness of the sample strip was measured in about 50 millimeter intervals along the length of the sample strip and then averaged. The average thickness of the sample strip was then used to calculate the dry density of the sample strip, using the weight and dimensions of the sample strip. The wet density of the sample strip may be determined by ASTM D5729-95, which is hereby incorporated by reference as if set forth herein verbatim, after the sample strip has evaluated for Liquid Flux values.

Absorbent Capacity Vertical Wicking Test

The objective of this test was to quantify the ability of a given absorbent material a) to wick saline to relatively high height (13 - 17 cm) and b) to retain the liquid at the height between the 13th and 17th cm.

The performance of UCTAD/SAP composite structures were quantified by efficiency in moving liquid up against gravity and transferring it from the UCTAD tissue to the retention component.

Various techniques can be used to measure the amount of saline contained in the absorbent material after wicking such as gravimetical analysis (liquid balance before and after the wicking) or X-ray densitometry. Although the latter method is reliable and convenient, it requires the use of custom made equipment. The former approach may be replicated by one skilled in the art.

In this method, a 23 cm by 5 cm sample is cut out from an absorbent material, for example, from a laminate structure made with distribution tissue and retention component (SAP, SAP and fluff mixture, SAP fibrous nonwoven). The sample is weighed to

calculate the weight of its 4 cm length and placed in the Vertical Wicking Apparatus as shown in Figure 5. The wicking time was established at 30 min. to allow for equilibration of the tested material. After 30 min., the upper segment of the tested sample (between the 13th and the 17th cm) was cut out and weighed.

To calculate the Absorbent Capacity (in g of liquid per g of dry material) at the 13-17 cm height, the above upper part was dried (22 hours, 105°C) and wet weight was compared with the weight after drying. The dry weight of the 4 cm segment was calculated from the weight recorded before the wicking experiment and compared with the wet weight.

When the dry weight of the 4 cm segment was calculated from the weight recorded before the wicking experiment and compared with the wet weight, additional analysis of the sample may be analyzed after wicking. The partition of the liquid was quantified between the UCTAD material and the retention layer by separating these two components and then recording wet weights and the weights after drying (22 hours, 105°C).

The vertical distances from surface of the solution to the liquid front traveling up the sample strip and the liquid weight absorbed by the sample strip were recorded at various times. Not more than 30 seconds should elapse between successive height, weight, and time recordings. Depending on how quickly the liquid front travels up the sample strip, it may be appropriate to record measurements more frequently.

Referring now to Figure 7, a wicking test apparatus 50 is shown having a reservoir of liquid 52 in aspirator bottle 54 positioned on a balance 55. Liquid feed is passed in line 56 to liquid distributor 58. Sample 60 is placed by ruler 62 having graduated mark 64 at a distance of 5 cm up the ruler 62, graduated mark 66 at a distance of 10 cm up the ruler 62, and graduated mark 68 at a distance of 15 cm up the ruler 62. An automated apparatus

70 having electrode feeds 72, 74, and 76 to computer 74 may be substituted for the manual visual measurements, and accuracy and precision of measurements may be enhanced relative to manual visual measurements.

5 A plot of the liquid front height versus time was used to determine the Wicking Time to about 5 centimeters and to about 15 centimeters. The weight of the liquid absorbed by the sample strip was plotted versus time. The Vertical Liquid Flux value of the sample strip at a particular height was the slope of the weight versus time plot at that height, in grams per centimeters, times the length of the sample strip in centimeters divided by the mass of the sample strip in grams, as shown in Equation 2.

15

$$\text{Eq. 2} \quad \text{Vertical Liquid Flux} = \frac{(M_e - M_d) \times L_s}{(T_e - T_d) \times M_s}$$

where:

T_e represents recorded time e, in seconds; T_d represents recorded time d, in seconds;

M_e represents weight measured at time e, in grams;

M_d represents weight measured at time d, in grams;

L_s represents the length of the dry sample strip prior to testing, including the portion of the strip that is submerged in the test solution during testing, in centimeters; and

M_s represents the mass of the dry sample strip prior to testing, in grams.

The terms "d" and "e" represent successive times at which height and weight were measured in the series of measurements a, b, ..., d, e, ..., z. The time required for the liquid front to reach 5 or 15 centimeters was between d seconds and e seconds.

When determining the slope of the weight versus time plot for the

purpose of calculating the Vertical Liquid Flux, it is preferred to use more than two weight and time values near the desired height. Various graphical and statistical techniques confirm accuracy of the estimate of Vertical Liquid Flux at either 5 or 15 centimeters.

While the invention has been described in detail with respect to specific embodiments thereof, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing, may readily conceive of alterations to, variations of, and equivalents to these embodiments. Accordingly, the scope of the present invention should be assessed as that of the appended claims and any equivalents thereto.

WHAT IS CLAIMED IS: